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BIODIVERSITY
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WHAT IS AN HERBARIUM AND HOW DOES IT HELP US PROTECT BIODIVERSITY?

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YOUNG REVIEWERS:

AHA!
AGES: 13–14

PRANAV
AGE: 9

SONIKA
AGE: 10

THAKSITA
AGE: 7

When scientists study plants, they often collect, preserve, and store parts of the plants in a big collection called an herbarium. These plant specimens serve as proof that a species was growing in a certain place at a certain time. Herbaria ("herbaria" is the plural of herbarium) are where scientists describe new plant species and study how different species are related. Herbaria also contain lots of information about where certain plant species grow, what type of habitats species like, and at what time of year plants bloom and make fruits. Finally, herbaria are powerful tools for helping us understand how plants are affected by disturbances like habitat destruction and climate change. For all of these reasons, herbaria allow us to better understand and protect plant species all over the world. To continue benefitting from herbaria, we need to keep collecting plants and make these collections accessible to the world.

WHAT IS AN HERBARIUM?

When early naturalists and botanists collected plants from mountains in Nepal or the Amazon rainforest in Peru, they had no idea that their collections were going to help protect these habitats in the future. New and old plant collections have become powerful tools and can help us protect plants from things like habitat destruction and climate change.

When botanists study plants, they often collect specimens to take to an **herbarium** (plural = herbaria) for further study. These specimens usually contain samples from each part of a plant including its leaves, stems, flowers and/or fruit, and sometimes even roots. In the herbarium, the specimens get flattened in a device called a plant press, dried in an oven, glued to sturdy paper, and stored in climate-controlled cabinets where they will be preserved for hundreds of years (Figure 1). So, in other words herbaria are simply huge libraries of preserved plant specimens. Today, there are more than 3,000 herbaria around the world that together contain almost 400 million plant specimens!

HERBARIUM

An organized collection, like a library, of plant specimens. Herbaria are often found in museums, botanical gardens, or universities and cared for by a dedicated staff.

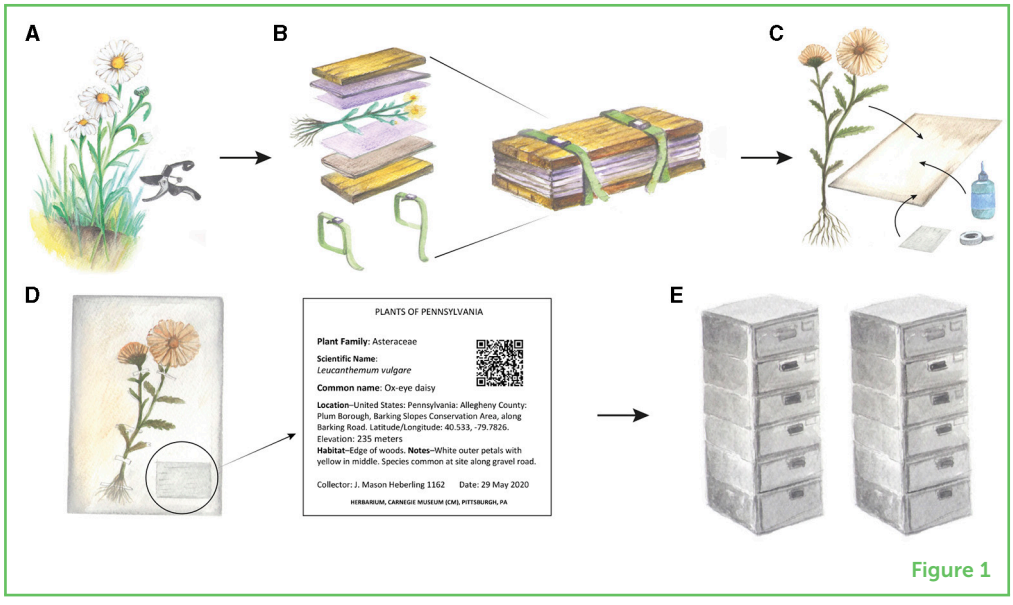

Figure 1

How to make an herbarium specimen. **(A)** First, collect a plant from the field using clippers. **(B)** Put the plant in newspaper or blotting paper and put a layer of cardboard above and below for support. Flatten and dry the plant in a plant press. **(C)** Once dry, glue the plant to special herbarium paper, along with its label. **(D)** The completed specimen has a label that includes the plant family, scientific name, location, plant description, and who collected it. **(E)** Store the specimen in climate-controlled cabinets in the herbarium for future research (Figure credit: G. Enríquez).

VOUCHER SPECIMENS

Preserved plants or parts of plants collected during a scientific study, as evidence of what was studied and for future use.

Plants are often collected as **voucher specimens** during scientific studies. Voucher specimens are essential during the scientific process since they are proof that a plant was growing in a certain location at a particular time. Sometimes, vouchers are used as references by other scientists if they want to identify similar looking plants or when they want to describe new species. But, as you will see below, scientists are still discovering new uses for these voucher specimens many years after they were collected.

A good plant specimen includes important information about the plant, including its scientific name, exactly when and where the plant

was collected, who collected it, and other notes such as the plant's size, its flower color, its scent, the way people use the plant, the type of habitat where it grew, and more. Scientists can use this information to know exactly where certain plant species grow, the time of year a species produces its flowers and fruit, and how species are related to each other. Herbarium specimens also serve as "time capsules" to tell us which plants used to grow in various areas and how the world is changing through time.

When picturing an herbarium in your mind, you might imagine dark and dusty rooms crammed with cabinets full of dried leaves. In fact, herbaria are very clean and active places of research, and many herbaria have recently begun the process of **digitizing** their collections [1]. Today, virtual herbaria such as the New York Botanical Garden's Virtual Herbarium (https://sweetgum.nybg.org/science/vh/) contain photographs of millions of specimens along with information about the date and location of each collection. All this information is now being gathered into online databases where specimens from thousands of herbaria around the world are combined into publicly available webpages. By visiting just a single webpage (for example, https://www.gbif.org/), scientists can easily access information about almost 100 million specimens, including more than 40 million photographs [2]. This number is growing every day!

DIGITIZING

The process of converting physical objects or information, like a plant specimen, into a digital format.

Before we had virtual herbaria and online databases, scientists had to travel to herbaria in various countries and look through thousands of specimens to find the information they needed about the species they were studying. Now, anyone can access all this information from a computer or even a phone! Now that scientists have such easy access to so much information, they can make maps of where rare and endangered species are growing, they can study why some plant species live in some places but not others, they can look at the effects of climate change on plants, and they can work to protect plants from threats like climate change and land use.

YOU CANNOT PROTECT A SPECIES IF YOU DO NOT KNOW *WHAT* IT IS

One of the most important uses of herbaria is **taxonomy**. Taxonomy is a field of science in which scientists describe new species and organize them into closely related groups. Specimens in herbaria are necessary when a scientist wants to describe a new plant species. For a long time, describing new species was done just by looking at the **morphology** (size, shape, and form) of the plants. These days, taxonomists also often use the genetic information in a plant's DNA [3]. Certain sections of a species' DNA can be thought of as its unique fingerprint. By comparing the DNA between plant specimens, scientists can study how the plants are related to one another. In some cases, DNA may tell taxonomists that what they thought was a single species is actually

TAXONOMY

The study of naming and classifying organisms in levels and groups, placing them in relationship to the larger tree of life.

MORPHOLOGY

The physical form and external structure of things, such as flower color, leaf shape, and growth form.

several different similar looking species! Scientists can collect DNA from dried leaves by taking a small piece to a sterile lab, grinding it up, and mixing it with chemicals to extract the DNA. They then use a special machine called a sequencer to read the DNA's code. Herbaria are great places for scientists to collect DNA from plants of many species and from many places.

YOU CANNOT PROTECT A SPECIES IF YOU DO NOT KNOW *WHERE* IT IS

DISTRIBUTION

The way a species is spread out over an area. A species' distribution relies on the environmental conditions it prefers.

Scientists also use herbarium collections to map where species live. To map a species' **distribution**, scientists make a map of all the locations where the species has been collected. Then, the scientists use the map and special computer programs to determine exactly what types of areas that species can grow in. In other words, does the plant species grow only in hot places or only in cold places? Only in dry or only in wet places? On mountainsides or in valleys? After scientists know which type of environment a plant species likes, they can identify other places that have the right conditions. In other words, they can guess where a species might grow even if no one has looked for the plant there yet. In some cases, scientists have used these guesses to find unknown populations of rare plant species.

Maps of where species live are also extremely valuable for conservation. Maps allow scientists to identify which species are threatened by development or habitat loss and which species are relatively safe. For example, if a forest is being cut down, it is likely that the species growing there are in trouble. This information can then be used to direct conservation efforts to help protect the species that need the most help.

Maps of where species live not only tell us how plants may be hurt by current threats like deforestation, but they can also help scientists predict how some plants will be affected by new and future threats, like climate change [4]. As habitats change due to rising temperatures or changes in rainfall, to stay in their preferred conditions plant species will have to change where they grow (Figure 2).

HERBARIA KEEP TRACK OF WHEN PLANTS BLOOM

PHENOLOGY

The timing of biological events such as springtime flower production.

Some researchers are also using herbarium specimens to look for changes in **phenology**, or the timing of flowering, fruiting, and leaf production [5]. Since the herbarium specimens usually include flowers (or fruit), the dates that these samples were collected tells us when a species produces flowers. If we look at the time of year that a species has been collected, we can see how climate change influences flowering times. Using this technique, we now know that many plant species from all over the world are making their leaves or flowering

Figure 2

Maps of the current and predicted distributions for two types of trees: **(A)** Laurel oak and **(B)** Virginia pine. Distribution maps are made by looking at the conditions and climate where the species have been collected. Scientists predict that many plant and animal species will change where they grow in the future, due to climate change (Figure credit: G. Enríquez).

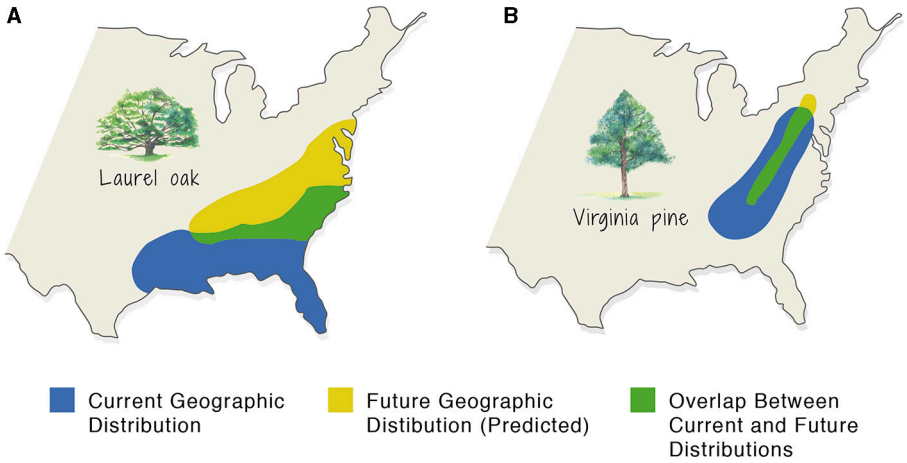

Figure 2

Figure 3

(A) Red maple trees collected in March have flowers. **(B)** Collections made in April include fruits and seeds. **(C)** Collections made in May have young leaves. **(D)** Using herbarium specimens collected over the past 100 years, scientists have learned that Red Maple trees make their leaves earlier in years when spring temperatures are hotter. Spring temperatures have been increasing due to global warming (notice how there are many more blue points in the top left part of the graph and more red points in the bottom right part of the graph). Each point represents one herbarium collection (Figure credits: G. Enríquez; [6]).

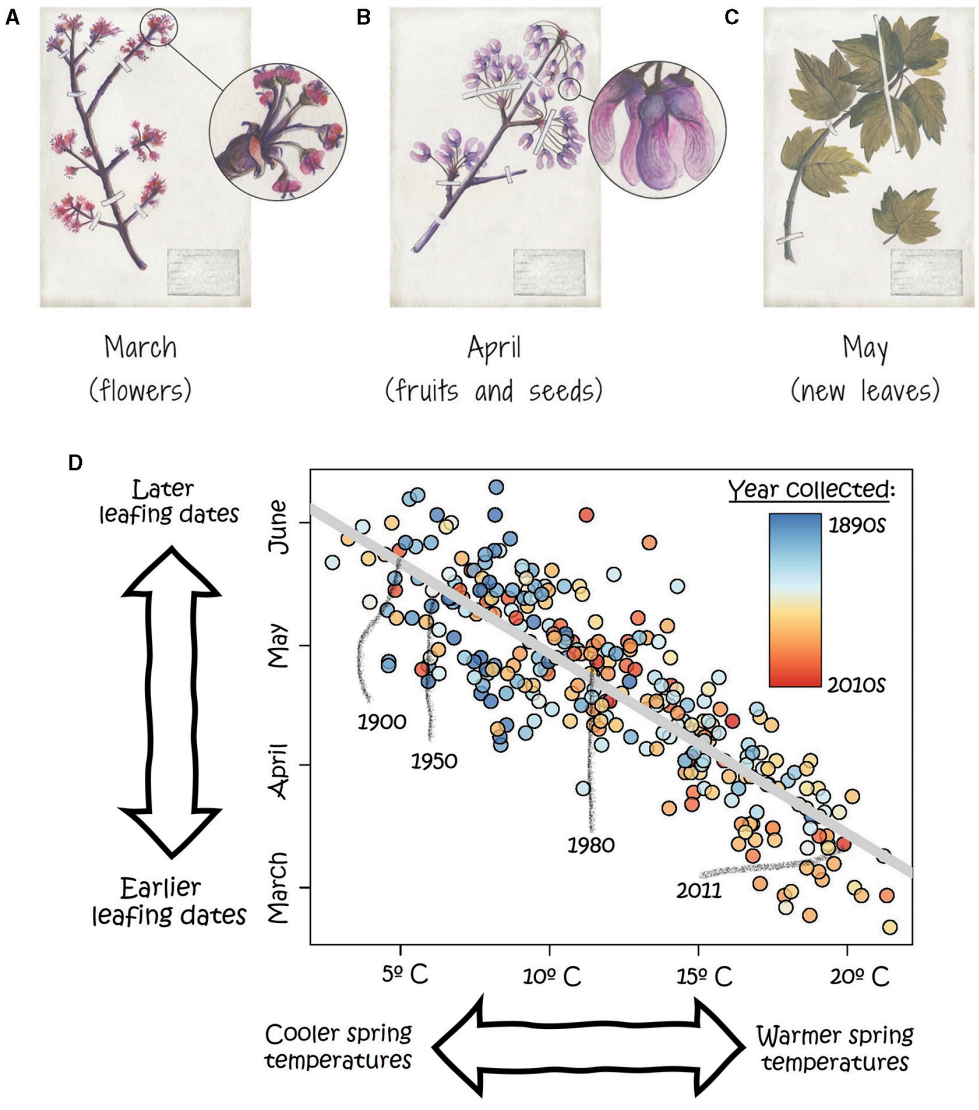

Figure 3

earlier and earlier each year (Figure 3). Some plants have been found to be making leaves or flowering weeks earlier now than they used to [6]. One explanation for earlier flowers is that global warming has made winters shorter, and spring is starting earlier each year. While a shorter winter and earlier flowers may seem nice, it can actually be bad news since many other species cannot match this new schedule. For example, imagine what will happen if trees start flowering earlier in the year but the bees that pollinate them do not wake up from their winter slumber until the trees' flowers have already wilted!

HERBARIA'S ROLE IN FUTURE RESEARCH

Plant specimens are being put to new uses in ways that early botanists and collectors never dreamed of. Additionally, these collections will continue to be used in ways we have not thought of yet. Herbarium collections are one of our greatest sources of information about plants and are also one of our most powerful tools in studying the impacts of habitat change and global warming. But, for herbaria to be useful, they need to have lots and lots of collections. For example, to make a good map of where a plant species lives, we need dozens or even hundreds of specimens. Unfortunately, many rare plant species are known by just one or two specimens. Plus, thousands of plant species have still never been collected at all! How many of these wonderful species will we lose before they can be collected, identified, and mapped?

How do we get more information so that we can save more species? First, we must collect more plant specimens. This means that we need more people—people like you—getting excited about **botany** and collecting plants. Second, we need to continue photographing and digitizing the collections that herbaria already have, so that they are more accessible to people all over the world. Hopefully someday we will have enough information to protect all plant species!

BOTANY

The branch of biology that deals with the study of plants.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

AHA!, AGES: 13–14
The awesome AHA! crew is a trio of cool teens hailing from the beautiful states of Colorado and Virginia, USA. Their group name is a total brainwave—it's made up of their initials and perfectly captures the euphoria they experience when they crack the code of a fresh science concept. To complete this project, they met virtually, created online interactive quizzes, and participated in a citizen science research project to apply what they have learned.

PRANAV, AGE: 9

My name is Pranav. I am studying in grade 4. I am 9 and in 2 months I will be 10. In Science class, I am learning about energy and energy transfers. I like to draw and make comix. I do NOT like vegetables. My favorite subjects are Math and word study.

SONIKA, AGE: 10

My name is Sonika. I am studying in Lakshmi school. My favorite hobby is to draw and color. I like birds and animals very much. I like to study about birds and animals.

THAKSITA, AGE: 7

My name is Thaksita and I am in 2nd grade. I am 7 years old. I am interested in nature. In my free time I like to draw, play with my friends and search facts on my computer. I like to learn about any type or group of plants with friends. My favorite colors are pink, blue, purple, and red. My favorite sports are Gymnastics, Volleyball, and Roller-skating.

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Kenneth J. Feeley is a professor of biology at the University of Miami. He studies the ecology and biogeography of tropical forests. He is especially interested in understanding how climate change and habitat loss are affecting tropical trees. In his free time, Ken enjoys baking bread, carving wood, and hiking in the woods.